

Hydraulic Fracturing and Microseismic Monitoring Project
Bakken Research Consortium
Contract No. G-015-028

This is a project submitted by Headington Oil Company, L.P. and XTO Energy Inc. on behalf of the Bakken Research Consortium. The final group of participants in this project includes: Brigham Exploration, Continental Resources, Inc., Encore Operating, Headington Oil Company LLC (and XTO Energy, Inc as a result of its acquisition of Headington's Williston Basin assets), Hess Corporation, Petro-Hunt LLC and Whiting Petroleum as Working Interest Participants; and Schlumberger Oilfield Services, , MicroSeismic, Inc., Terrascience Systems Ltd, and the DOE National Energy Technology Laboratory in conjunction with the Lawrence Berkeley National Laboratory as Technical Participants.

The Bakken Consortium was conceived as an opportunity to deploy the most advanced available technology to investigate opportunities to optimize the drilling, completion and production of horizontal Williston Basin Bakken wells. Of special significance was the implementation of microseismic technology to monitor fracture initiation and growth. In an effort to maximize the potential for successful microseismic monitoring it was decided three parallel horizontal wellbores would be drilled within a 640-acre unit. Two of the wellbores would be completed using completion methods common to the Williston Basin. The middle wellbore would be used initially to deploy geophones horizontally in the Bakken to allow for microseismic monitoring of fracture stimulation. Completion of the monitoring well was considered for some future date. It was determined a pilot hole would be drilled and a core taken in one well and all three laterals would be logged. Further it was determined advanced LWD and MWD techniques would be used in the drilling of the second two wells.

The project area is located in Section 36-T156N-R95 W in eastern Williams County, North Dakota, on the eastern flank of the Nesson Anticline. The primary operational phase of the project has been completed. All three wells have been drilled; both producers have been completed and stimulated and are currently producing. All data has been collected, analyzed and presented to consortium members. The project remains on schedule as outlined in the North Dakota Oil and Gas Research Council application. Pertinent aspects of the drilling and completion phase are summarized below. The status of key events related to this phase of the project is as follows:

- All three wells have been drilled
- Downhole geophones were successfully deployed in the monitoring well
- Two buried and one surface array were successfully deployed to monitor stimulation
- Both producing wells have been fracture stimulated
- Primary fracture stimulation has been monitored by four microseismic arrays
- All microseismic data has been processed and relayed to consortium members
- \$12.98 million in drilling and completion costs have been incurred to date
- \$0.5 million in 3D-seismic costs have been incurred to date.

The data gathered during the project will impact the operational programs of each participant in a unique way. The most significant applications will impact producers' completion and fracture stimulation techniques, however, the drilling phase of operations may also be impacted. While the impact on each operator's program will be unique, XTO has identified several conclusions which will affect their program. They include:

- Due to data gathered through the Consortium project XTO has proposed a multi-well program of coring and pilot holes to study frac barriers and reservoir dynamics.
- There appears to be a correlation between perforations and fracture initiation. XTO is investigating the opportunity to perforate previously completed wells before refracs to better distribute stimulation treatments.
- Given the apparent correlation between perforation and fracture initiation, XTO believes the "plug and perf" method of staged completions is a more effective means of stimulating the wellbore.
- The magnitude of maximum stress is close enough to that of minimum stress that XTO believes in most cases wellbore orientation has little impact on induced fracture orientation.
- The microseismic data from each of the four data sets appears to be in conflict to a significant degree.
- Due to the apparent disagreement in the microseismic data as well as the cost and operational complexities associated with microseismic investigation, it is unlikely XTO will pursue further microseismic investigations independent of the Consortium.
- The signal to noise ratio in the Bakken is low enough that if future microseismic operations occur, care will need to be taken to maximize signal strength.
- Based on data gathered during logging of the three wells and supported by microseismic data, XTO believes that most induced fractures will grow at some angle oblique to the wellbore. Given this assumption, XTO believes wells completed using staged completions (i.e. external casing packers) will be as productive with fewer zones (5 to 6) as with more zones (15 to 20). XTO recognizes not all participants in the Consortium agree with this conclusion.
- While XTO recognizes the need to maximize the amount of wellbore in the target zone, XTO does not believe the data gathered by advanced LWD/geo-steering techniques offsets the cost or operational problems associated with the technology.
- Based on frac modeling done on gathered data, it is likely fracs are growing into the Three Forks but may not be effectively propped open.

Extensive detailed information on this project is available in the full report which can be accessed from the Oil and Gas Research Program/Industrial Commission's website at: **Detailed Final Report**